ISSN: 1693-1246
Juli 2011

Jurnal Pendidikan Fisika Indonesia 7 (2011): 134-137

http://journal.unnes.ac.id

MAGNETIC PROPERTIES OF SUSPENDED OF POLLUTED HEAVY METAL SEDIMENTS FROM SEMARANG RIVERS

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Diterima: 3 April, Disetujui: 4 Juni, Dipublikasikan: Juli 2011

ABSTRAK

Sifat magnetik, dalam bentuk kerentanan magnetik, tergantung pada frekuensi kerentanan (CFD) dan magnetisasi remanen isotermal (IRM) diukur pada nilai sampel yang terbuat dari sedimen tersuspensi dari Semarang sungai terdekat, Jawa Tengah. Semarang adalah salah satu kota besar di Indonesia, dimana sistem sungai yang sangat mungkin terkontaminasi oleh kegiatan antropogenik. Tujuan dari penelitian ini adalah untuk mengidentifikasi adanya logam berat dalam sedimen yang akan menentukan kesesuaian sedimen untuk studi lanjut magnetik lingkungan. Hasil menunjukkan bahwa kerentanan magnet bervariasi 58-3585 10-8 m3/kg, sementara kerentanan tergantung pada frekuensi kurang dari 3% menunjukkan dominasi mineral feromagnetik. IRM analisis menunjukkan bahwa semua sampel jenuh dalam medan magnet kurang dari 200 mT menunjukkan mineral yang dominan adalah magnetit (Fe3O4). Membandingkan pengukuran magnetik dan analisis kimia, kami menemukan korelasi yang baik antara suseptibilitas magnetik dan konsentrasi Fe, Mn, Co, dan Ti.

ABSTRACT

Magnetic properties, in the form of magnetic susceptibility ©, frequency-dependent susceptibility (cfd), and isothermal remanent magnetization (IRM) were measured on scores of samples made of suspended sediments from rivers nearby Semarang, Central Java. Semarang is one the major cities in Indonesia, where the river systems are very likely to be contaminated by anthropogenic activities. The objective of this study is to identify the presence of heavy metals in the sediments that will determine the suitability of these sediments for further environmental magnetic study. The results show that magnetic susceptibility varies from 58 to 3585 10-8 m3/kg, while the frequency-dependent susceptibility is less than 3% indicating the predominance of ferromagnetic minerals. IRM analysis shows that all samples saturated in magnetic field of less than 200 mT suggesting the predominant mineral is magnetite (Fe3O4). Comparing magnetic measurements and chemical analyses, we found good correlation between magnetic susceptibility and concentration of Fe, Mn, Co, and Ti.

Keywords: magnetic susceptibility; heavy metals; river sediments; Semarang.

INTRODUCTION

In many cities in the developing world, rivers are often used as large sewers receiving an enormous amount of anthropogenic waste. Apart from clogging the riverbeds, the waste also bring many forms of pollutant, including heavy metals, such as Pb, Cd, Cu, and Zn [DeKimpe and Morel, 2000]. Considering their serious effects to health and environment, detection and monitoring of heavy metals are of outmost importance. In recent years, rock magnetism has provided one of the methods in the detection of heavy metals by magnetic susceptibility measurements. Correlation between magnetic susceptibility and concentration of Zn, Pb, and Cd has been reported in Polish topsoil [Schmidt et.al, 2005], in urban soils in China [Lu and Bai, 2006], as well as in leachate from Indonesia [Huliselan and Bijaksana, 2006].

In this study, we conducted detailed magnetic susceptibility measurements and chemical analyses of suspended sediments taken from rivers near Semarang. The objective of this study is to identify the presence of heavy metals in the sediments that will determine the suitability of these sediments for further environmental magnetic study. Semarang is a major industrial cities and home to many industries that would very likely to produce waste containing heavy metals.

METHODS

Mud and suspended sediment samples were obtained from four different river systems near Semarang namely Kali Beringin (Kl Brg), Kanal Barat (Kn Brt), Kali Semarang (Kl Smg), and Kanal Timur (Kn Tmr). Within each system, samples were taken from a number of sites (three for Kanal Barat and four for the other river systems). The geographic coordinates of sampling sites are given in Table 1.

A total of 116 samples were measured for magnetic susceptibility (8 samples from each sampling sites, except for Kanal Barat where only 7 samples were obtained). Magnetic susceptibility was measured using a Bartington MS2B magnetic susceptibility meter at dual

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frequencies (470 and 4700Hz). Frequency dependent susceptibility, fd was expressed as

$$fd \quad \frac{lf \quad hf}{lf} x100\% \tag{1}$$

where lf is the low frequency magnetic susceptibility and hf is the high frequency magnetic susceptibility.

Table 1. Location of sampling sites

Geographic Coordinates			
Kl Brg	Kn Brt	Kl Smg	Kn Tmr
6°57'12.5 S 110°19'04.8 E	6°56'53.0 S 110°23'44.6 E	6°57'15.8 S 110°24'34.1 E	6°56'28.2 S 110°26'40.7 E
6°57'48.2 S 110°24'39.3 E	6°57'58.2 S 110°24'1.7 E	6°57';31.8 S 110°24'52.0 E	6°56'59.5 S 110°26'27.1 E
6°58'19.9 S 110°24'26.1 E	6°58'52.2 S 110°24'16.2 E	6°57'38.3 S 110°25'01.8 E	6°57'38.2 S 110°26'32.1 E
	6°59'43.4 S 110°24'7.1 E	6°57'51.0 S 110°25'18.0 E	6°58 '24.6 S 110°26'33.6 E

Selected samples were also subjected to ARM (anhysteretic remanent magnetization) and IRM (isothermal remanent magnetization) analyses to infer the predominant magnetic mineral and its domain state. ARM was imparted using a Molspin AF demagnetizer using a DC current of 0.05 mT. The ARM was measured using a Minispin magnetometer followed by series of demagnetization processes to obtain an ARM decay curves. IRM was imparted using an electromagnet and measured using a Minispin magnetometer. IRM was given in a stepwise fashion by increasing the field inside the electromagnet. The results are plotted as IRM acquisition curves. All magnetic measurements are performed at the rock magnetic facility at Bandung Institute of Technology. Meanwhile, chemical analyses for four representative samples (one from each river system) were conducted using an X-rays Fluorescent or XRF (ARL Advant XP+, Thermo Electron Corp) at the Quaternary Geology Laboratory of the Indonesian Center for Geological Survey.

RESULTS AND DISCUSSION

Magnetic minerals in suspended sediments might be of lithogenic or anthropogenic origins. Earlier work [3] has suggested origin of magnetic minerals can be inferred from plots of lf over fd as natural magnetic minerals would tend to have low values of lf but high values of fd (more than 4%) whereas polluted samples tend to have high values of lf but low values of fd (3% or less). Figure 1 shows the plots of lf over fd for our samples. It shows that our samples have relatively high values of magnetic susceptibility ranging from 58 to 3585 10-8 m3/kg, while the frequency-dependent susceptibility is less than 3% indicating that the predominant magnetic minerals are of anthropogenic origin.

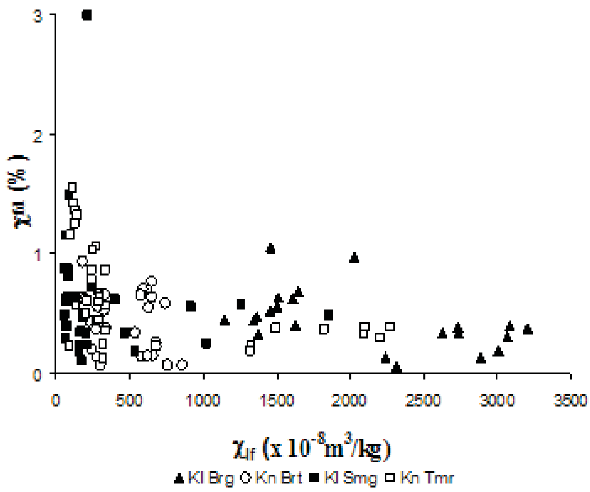


Figure 1: Plots of frequency dependent susceptibility as a function of low frequency magnetic susceptibility showing that most samples show relatively high values of low frequency susceptibility and low value of frequency dependent susceptibility.

Figure 2 shows the IRM acquisition curves for four representative samples. It shows that all samples saturate in magnetic field of less than 200 mT suggesting the predominant mineral is magnetite (Fe3O4). Figure 3 shows the ARM decay curve for representative samples. It shows that the ARM decay almost instantaneously showing unstable remanence. We could infer that the samples contain high proportion of coarse multi-domain magnetic particles.

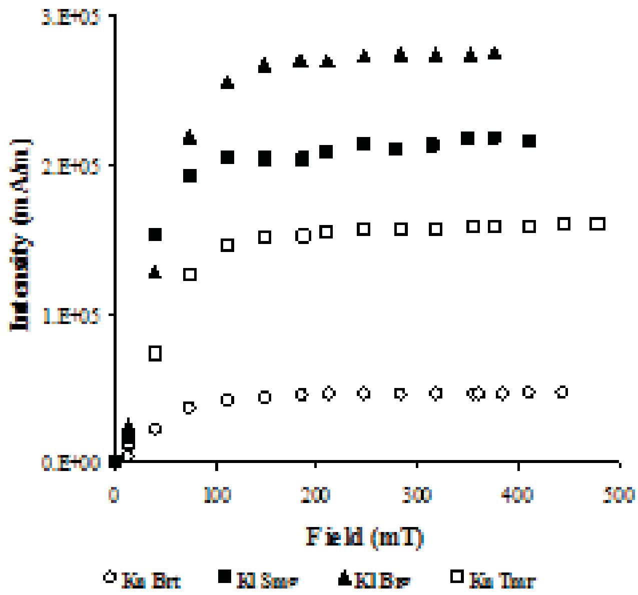


Figure 2. IRM acquisition curves of four representative samples showing that all samples saturate in magnetic fields of less than 200 mT.

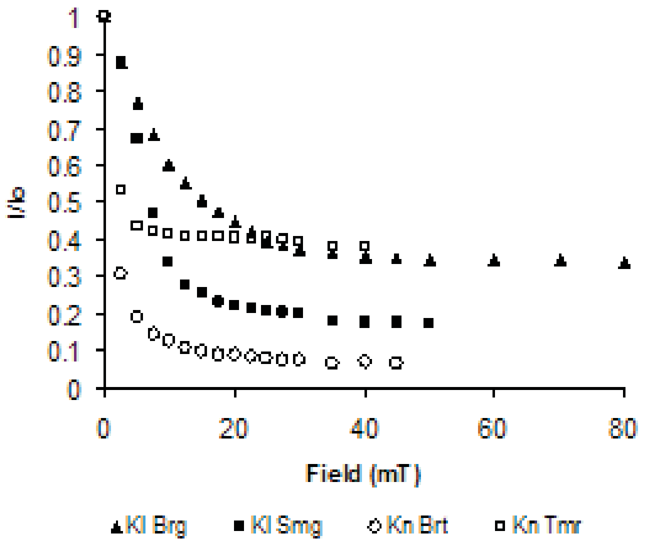


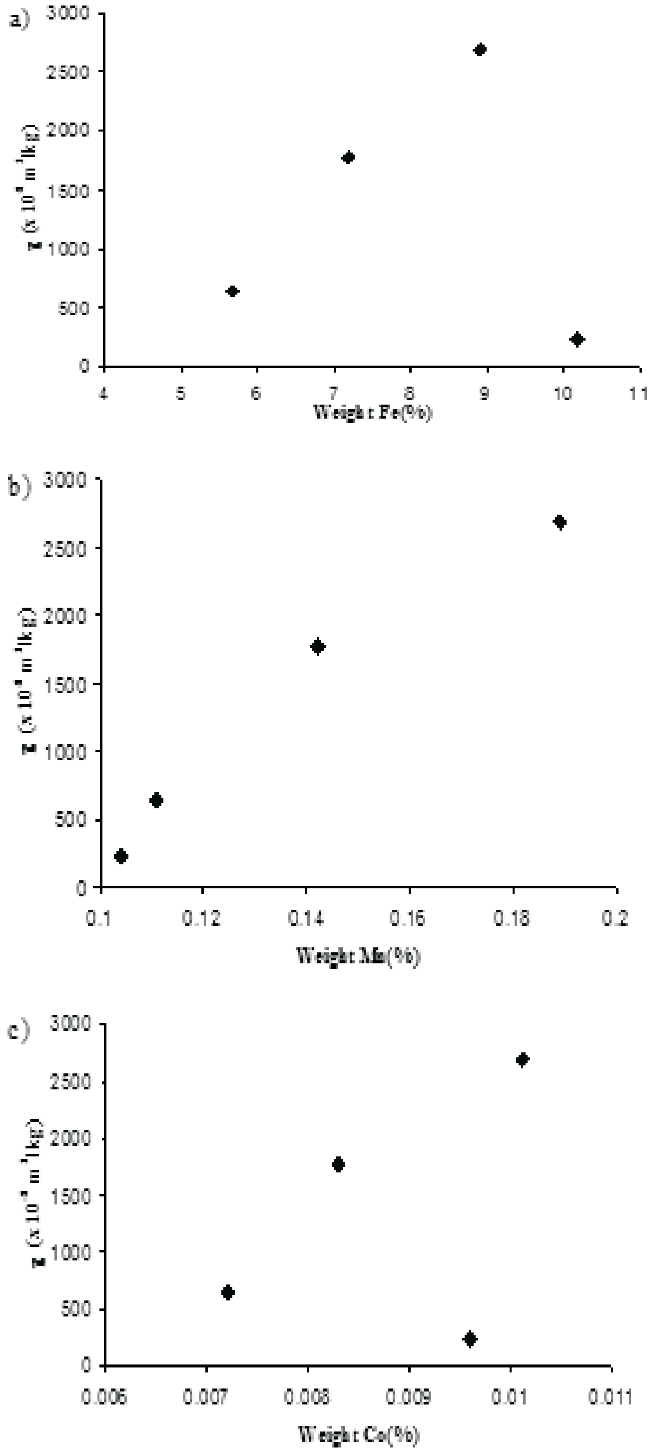
Figure 3. ARM decay curves for four representative samples showing that the remanences are unstable. The predominant magnetic mineral is likely to be coarse-grained.

Table 2 shows the results of quantitative chemical analyses. Kali Semarang shows the highest concentration of lead (Pb) inferring that this system is most polluted one. This is also supported by its high concentration of iron. However, compared to chemical composition of other river system in the developing world, for example the Pasig River system near Manila, Philippines [Garcia et.al, 2003], all river systems observed in Semarang show higher level of heavy metal content.

Table 2. Elemental compositions of suspended sediment samples

Element	Weight (%)			
	Kl Brg	Kn Brt	Kl Smg	Kn Tmr
Al	11.7000	11.3400	10.0200	10.3200
Fe	8.9000	5.6700	10.1800	7.1900
Mg	0.9120	1.0000	1.2700	1.0200
Ti	0.8460	0.5420	0.4320	0.6480
Mn	0.1890	0.1110	0.1040	0.1420
Zn	0.0120	0.0121	0.1070	0.0141
Co	0.0101	0.0072	0.0096	0.0083
Cu	0.0068	0.0060	0.0175	0.0060
Pb	0.0032	0.0040	0.0252	0.0029
Cr	0.0039	0.0034	0.0082	0.0036
Ni	0.0018	0.0031	0.0035	0.0023
As	-	-	0.0031	0.0010
Hg	0.0008	-	0.0007	-

Figure 4 shows the relationship between the average magnetic susceptibility and concentration of selected heavy metal elements (Fe, Mn, Co, and Ti). It shows that the average magnetic susceptibility tends to increase as heavy metal content increases. This positive correlation between magnetic susceptibility and Fe content is understandable as Fe is a strongly magnetic element. However, association of magnetic susceptibility and other elements (Mn, Co, and Ti) are not obvious as these elements themselves are not magnetic. There is, however, a possibility that the abundance of these elements is linked with the abundance of Fe. At this stage, we did not test the above correlations statistically due to the limitation in the number of data.



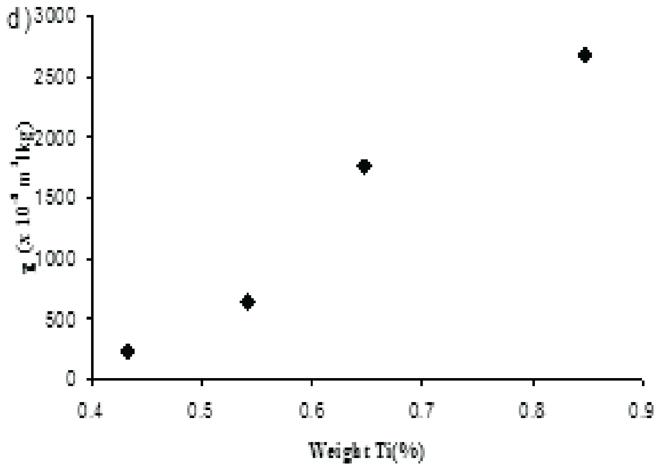


Figure 4: Plots of average magnetic sus-ceptibility versus heavy metal content: Fe (a), Mn (b), Co (c), and Ti (d).

CONCLUSIONS

Based on magnetic measurements and chemical analyses, we found that the suspended sediment samples taken from four river system near Semarang show correlation between magnetic susceptibility and heavy metal contents. The results also show that the predominant magnetic mineral is magnetite, most likely in coarse grain form. Measuring the frequency dependent susceptibility, we also learn that the magnetic mineral is anthropogenic in origin.

ACKNOWLEDGEMENTS

This research is a part of collaboration between Semarang State University and Bandung Institute of Technology and is supported financially by a research grant (HIBAH PEKERTI) from The Ministry of National Education of the Republic of Indonesia.

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